SCIENTIFIC DRAWING IN BIOLOGY.

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Drawing is done with one of three purposes in mind:

1. By the student as a record of his laboratory work.
2. For teaching purposes on blackboard or chart.
3. For reproduction in the illustration of scientific articles.

AS A RECORD OF THE STUDENT'S WORK.

Scientifically not free hand drawing. Free hand drawing is intended to suggest to the observer, to cause his mind to supply what is lacking in the representation. Scientific drawing is a precise record of specific details.

All agree that the mechanical reproduction of details of structures studied is a highly valuable means of aiding the powers of observation, the memory and therefore preserving material with which to think. Reduced to the lowest terms a laboratory drawing is a careful proportional outline of two dimensions of the object studied. It is a graphic record of mental impressions received through the eye. All the important points should be fully labeled in a neat manner. It is then not a question of artistic ability but of ability to measure and to record the data. The alleged inability to draw of which the teacher is often told is merely a confession of unwillingness to be precise in measuring or recording or both.

Boundaries of structures are what is desired, shadows, colors or curvatures or other such phenomena are not needed. These secondary details, if put in, conceal the accuracy or inaccuracy of the student's measurements and therefore of his observations.

A drawing should be to scale and in my opinion, larger than natural size whenever the size of the object and of the drawing paper permit. The beginner is likely to draw what he sees through the microscope too small so that he is unable to put in the details adequately. He should be warned along this line at the first meeting. If the student draws a faint vertical line in the region which is to be the chief axis of his drawing, he may

locate the important points of his specimen proportionately on this line. The width of the specimen to the scale of magnification selected may then be laid off at these points. When a sufficient number of points in the outer boundary of the drawing have been located thus by precise measuring, a faint line may be drawn through them, giving the outline of the specimen. The outline should then be compared with the dimensions of the original and any lack of proportion corrected. Then the outlines of appendages or of interior structures may be put in.

Any important line in an object may be projected to the other side of the outline of the object. Any two points in a drawing may be connected by a line and this line continued until it strikes some other important structure. This is a valuable way of checking the correctness of the proportions of the drawing and as the lines need not be actually drawn, the process of checking up can be a very rapid one.

It helps the beginner if he is asked to partially close both eyes as he looks at the specimen being studied, for the important lines and especially the boundary lines persist after the details of color or marking disappear.

All the constructional lines should now be carefully removed. The boundary lines of all structures must be definite continuous clear-cut lines. If the drawing is to be inked over, the pencil boundary should be left faint and does not need to be made so uniform as if the pencil is to be the final instrument.

The lines leading from structures to their names, known as lead lines should be very carefully made. They should be horizontal and parallel to the top and bottom edges of the drawing paper though exceptionally they may be vertical lines. They should be discontinuous or broken lines with the parts of about equal length. This enables one to distinguish lead lines from structural lines at a glance. As a transparent ruler for making lead lines a common 3 x 1 glass slide is very satisfactory.

The drawing should be labeled at the top with an identification mark, either a serial number or the name of the organism from which it was taken and should bear the student's name or initials. The date is also desirable unless this is stamped on by the critic at the close of each laboratory period.

SCIENTIFIC DRAWING FOR TEACHING PURPOSES.

Blackboard Drawing.

Blackboard drawing is most important. It is rapid and is simultaneous with or follows the explanation. This combination affects both sight and hearing and thereby makes mental efforts easier and more successful.

If you have complicated drawings to make, they should be done before the lecture. A thing which takes some time to make and which might be used more than once should be made as a chart which can be left hanging for reference. The simpler drawing constructed as the idea is being presented has great advantages as the student is able to transcribe it into his notes.

Do not shade a black board drawing since the natural order of things is reversed and the dark boundary is being reproduced as white. Make your outlines heavy for easy vision.

For differentiation of structures use such colored chalks as will easily show at the back of the room. It is artistically illegitimate, but you can give an impression of relief by using thicker lines where the shadows should be. This is useful, for example, in drawing cleavage.

A blackboard drawing is for the moment only and need possess little artistic merit. I have seen an elaborate blackboard drawing hamper teaching because it was made so well that no one had the heart to erase it.

Charts.

For making charts one should have a drawing table at least 52 inches wide whose four sides are squared so that a T square $4\frac{1}{2}$ feet long can be used on it. If you use the Metric system of measurement enlargements can be made more easily.

The best chart material is canvas backed bristol board. This can be purchased in various sizes. I have gotten two sizes. Rectangles, 16 inches by 24 inches, convenient for small diagrams and continuous rolled material a yard wide from which charts of any desired length can be made. Heavy Manila paper will do but is likely to tear along the edges after years of putting up and taking down. The smaller charts are easily hung using thumb tacks while the larger ones rolled on wood need some sort of hooks.

For enlarging drawings there are several methods possible.

1. Take an important axis and erect ordinates. Assume a scale of magnification and find the length of the axis magnified and locate the ordinates also magnified. This method reversed will also serve in case one wishes to reduce the dimensions of an object.

2. Use the method of small squares, drawing them faintly but definitely over the drawing to be enlarged, or outline the original drawing on transparent (tracing) paper and draw the squares over this outline.

Then on your chart draw squares whose dimension is the number of times larger than the small squares that you wish the drawing magnified and redraw on the new area, placing the points and lines on the large squares in positions corresponding to those shown in the small squares.

3. A modification of this method is to use a gelatin sheet, draw a net of squares on it with a sharp point. This may be placed over the picture and the outline traced as in No. 2.

If such a transparent outline be elevated and a small aperture arranged above it so that the eye looks from what is essentially one point the outline can be traced as projected on the chart on the drawing table. Large drawings can not be traced in this way because of one's inability to reach lines beyond a certain distance from the eye.

4. Use a Pantograph or multiplying apparatus. A good one costs $6–$8, the cheaper ones are useless.

5. By using a reflectoscope if you have one, you may project your diagram or drawing on the drawing paper pinned to the screen and outline it perfectly.

The order of making a chart is as follows:

1. Lay out the chart.

2. Copy figure with faint lines of a fairly soft pencil (3 H). Clean with a sponge rubber which will not spoil the grain of the paper if water color is to be used.

3. Put in shades. This will be described in the next section of the paper. For large shades use absorbent cotton and the color, and it will give a fairly evenly shaded area.

SCIENTIFIC DRAWING FOR REPRODUCTION.

Photography.

This is very useful for whole objects, gross dissections and the like, being precise and a great time saver.

The common photograph gives no color differentiation as most colors have too near the same value. If you have a print from the negative made on Whatman paper you can color on this. Never try to color from memory, always have the object or a similar one. One is likely to expect too much of micro-photography. Diatoms, Desmids, Bacteria, Golgi preparations, anything with clear outlines and single colors will give good results. High powers of things like cell division or tissues cells are not so satisfactory for the average photographer. The investigator himself sees a mental image into the photograph while outsiders are bothered by details and get an unsatisfactory image. A photographic plate does not distinguish between opaque and transparent structures. This can be expressed in water colors in a drawing. A photograph reproduces everything with equal value; a grain of dust, an air bubble, a crack or a fault in the section, all these are faithfully repeated. The microscopic field is not quite flat so that details near the edge will not show. One can photograph only one focus at a time, whereas your drawing is the result of the study of the structure at a number of levels. It gives the results of brain work on the facts before you. Everything in the drawing must be in the slide but everything in the slide does not have to be in the drawing. The drawing should be diagrammatic but not a diagram and is superior to the photograph both in clearness and in truth; in clearness because unnecessary things are omitted and in truth because the essentials are not obscured by unessentials as in the photograph.

Drawing.

A scientific drawing for reproduction should be made with reference to the method of reproduction. Of these there are several types.

It is obvious that those methods of reproduction will be cheaper which are entirely mechanical and can be carried through by the ordinary, intelligent workman. Those, on the

other hand, which involve great technical skill in the worker are expensive.

Etching on metal, lithography and wood cutting since they involve skilled technicians are costly reproductions as compared to the half tone method and the method of zinc engraving which utilize photography directly.

For all methods involving photography it is best to have black ink drawings on a white ground. Good pencil drawings can be used, but the ink gives the greater contrast.

In making drawings it is often necessary to transfer to a clean sheet of Bristol board or water color paper. Paste tracing paper with unboiled flour paste (which will not spot paper) on your drawing. Trace over the outlines lightly, then loosen the tracing paper, reverse it on a window pane or on the glass top of a box containing an electric light, go over the outlines with heavy, soft pencil, and by careful pressure you have the outline transferred to the fresh Bristol board. The use of carbon paper for transferring is somewhat dangerous as other blotches may be transferred to the clean sheet beside the lines which you wish. For erasing use sponge rubber or Fabers kneaded rubber so that you will not injure the surface for water colors.

To lay a flat tint use a brown or red sable brush—common camel's hair is not good. The brush should jar to a perfect point, it should be large so as to hold much liquid. It must be elastic so as to spring to position instantly. You must not lay it down flat, always keep brushes in a glass, point up, to preserve the point.

The water color paper or Bristol board must be wet all over first to keep from spotting it with your wash or colors. A camel's hair brush can be used to take up excess of color when laying a tint. If you have too much color, add water and take up with nearly dry camel's hair brush. The evenest washes are those made with Prussian blue, carmine, olive green, indigo, neutral tint, vandyke brown, most of the yellows. Those which dry too quick and so are likely to make spotty work, cobalt, vermillion, ultramarine, most of the greens, most of the blacks, burnt sienna and sepia unless very thin. When one wants very rich reds or browns as in drawing of kidney, it is not obtainable

with water color so finish the drawing and then put in the color wanted with pastel (crayon). This rubs badly unless fixed with shellac fixatif.

It is best to lay on several light washes instead of a heavy one to avoid spotting.

For the very finest lines or most delicate stippling in water color you can use a lithographic pen. For pen drawing waterproof ink is best; such as Higgins or Winsor and Newton. To get an even outline keep turning the papers so that you draw in the most favorable direction. Draw only short sections at a time so as to follow the boundary precisely.

Where you have heavy outlines to draw take a broken ebony scalpel handle, sharpen it like a pencil and let it soak a while in ink. Do not try to use it on your drawing first after the ink but on another piece of the same paper. This same thing holds with a ruling pen or a common pen. You can stipple or make small thick lined circles very nicely with this ebony point.

The shadow of an object is darker than the darkest shade on the object. It is tacitly accepted all over the world that the light is to come from the left side. In shading with ink to indicate rough surfaces use short, stubby lines, for smooth surfaces use long, fine lines, and for very light shades use fine, broken lines. These long lines should be drawn parallel to the surface you are shading. Never use over two layers of lines in a shadow and these never at right angles to each other. Shades can be stippled in and they will reproduce well. This requires great care in spacing to give the correct shadows and is hard on the eyes.

A drawing or photograph, can with advantage, be made larger than the size it is to be reproduced. If it is to be reduced to three-fourths of its size, that is known as one-fourth off. If to half the size, it is one-half off. Reduction can be carried only so far before the finer lines will merge into each other. The advantage of reduction is that if the drawing is made large, the lines can be made reasonably wide and uniform. Attempts at very fine lines usually result in lines of uneven width which reproduce poorly. All drawings which are to be on a single plate must be reduced in the same proportion.

This brings up the question of lettering. The letters used with a drawing or photograph that is to be reduced in reproduction must be chosen with the reduction in mind. Any shadows as of edges of paper can be removed from the zinc plate if they are far enough away from structures that must be kept so that the graving tool can cut them away. If none of the natural background of a structure in a photograph is wanted, the structure must be carefully cut out of its setting with a sharp instrument and pasted on a white surface. The lettering can then be placed on this. Cut-out letters of almost any size with gummed backs can be pasted on a plate unless this is to be rolled. Rolling up is likely to spring the letters off from their particular place and so ruin the labeling.

One will learn the method with which he is most successful by trial. Care in making drawings will always be repaid in the appearance of the printed paper. For the beginner ink-drawn text figures will probable be the most satisfactory. Photographs should be printed out by a method which will reproduce successfully. Those papers which have bluish tints should be avoided and also those which are finished with a gloss.

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